NOAA Technical Memorandum NMFS-SEFSC-446

RESULTS FROM THE LONG-TERM MONITORING OF NESTING LOGGERHEAD SEA TURTLES (*Caretta caretta*) ON WASSAW ISLAND, GEORGIA: 1973 – 2000

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INTRODUCTION

The southeastern U.S. is considered one of the most important loggerhead sea turtle (*Caretta caretta*) rookeries in the world (Bowen and Karl, 1997). The majority of loggerhead nesting in this region occurs in Florida (~90%), while only ~10% of the population deposit their eggs on barrier island beaches north of Florida (Dodd, 1988). Yet, these relatively small islands allow biologists the opportunity to develop and implement research practices and monitoring efforts that may not be considered cost effective or feasible on larger beaches where turtles nest en masse (Richardson, 1999).

The Georgia barrier islands remain in a relatively natural state because of their inaccessibility and the good stewardship of those who have owned them (Johnson et al., 1974). However, the future development of the coastal region of Georgia is now of major public interest. Various proposals for dredging, mining, recreational development, and preservation have stimulated much controversy in the press and at public hearings. Unfortunately, much of the information appropriate for making management decisions is lacking. Accordingly, data collected by long-term sea turtle monitoring programs have become increasingly valuable to government agencies for developing updated management plans throughout the loggerhead's nesting distribution (TEWG, 1996). Yet, much of the information that has been collected regarding the nesting ecology of loggerheads north of Florida remains largely unpublished (Witzell, 1998).

Here we present a summary of long-term data collected from nesting loggerheads on Wassaw Island, Georgia from 1973-2000. The purpose of this compilation is to make the results of our long-term monitoring data set available to other researchers that are working to elucidate the nesting ecology of loggerhead sea turtles. Whereas we provide limited discussions and comparisons between our results and nesting information reported from other areas, we hope that in the future the information presented herein can be used to formulate a comprehensive review of the nesting ecology of the loggerhead sea turtle. However, before any accurate comparisons can be made we must strongly encourage other long-term monitoring programs to make their data available to other individuals and institutions in a suitable report format.

MATERIALS AND METHODS

Study Site

Wassaw Island is part of the Wassaw National Wildlife Refuge located 12 km south of the South Carolina/Georgia border (Figure 1). The refuge consists of three islands: Wassaw, Pine, and Little Wassaw. Although loggerheads nest on all three islands, only Pine and Wassaw were monitored daily. The beach on Wassaw Island is ~ 14 km long and receives most of the nests recorded for the refuge. Since nesting turtles infrequently use Pine and Little Wassaw, these islands are not included in this summary.

Standard Beach Monitoring Data Collections

Prior to the start of the nesting seasons, the beach was sectioned off into 100-meter intervals for the purposes of mapping turtle activity. Each section was marked with a numbered PVC stake and placed on the first visible dune ridge. When a turtle or crawl was encountered its distance and direction from the closest numbered marker was recorded.

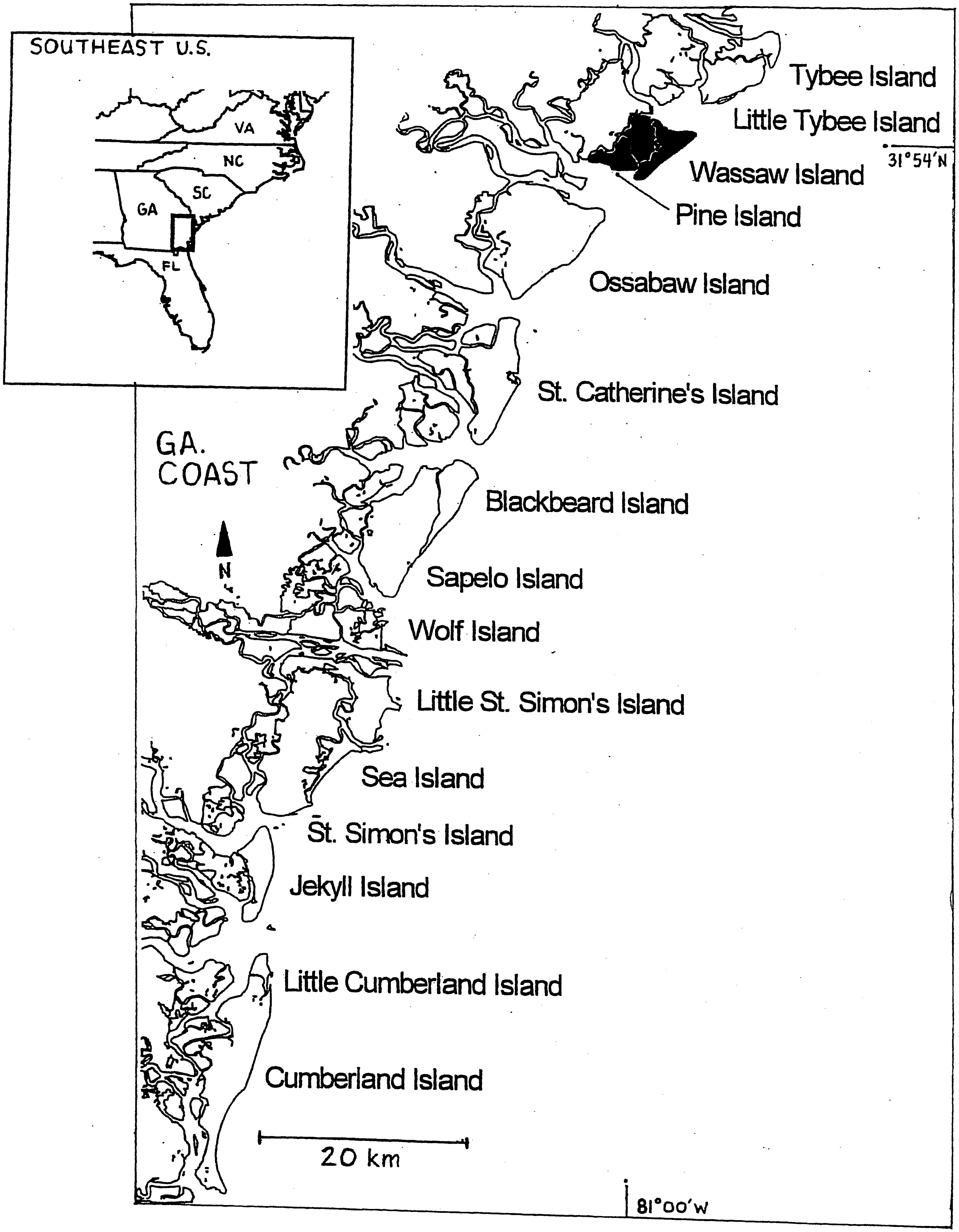


Fig. 1. Location of Wassaw Island on the Georgia coast.

Monitoring for nesting loggerheads generally started in early May and ended by the middle of August. Patrols began at dusk (~ 2100 h) and ended at dawn (~ 0600 h). Two teams of up to four people per team patrolled the beach. Patrols were conducted using three- or four-wheeled vehicles and/or by walking depending on the tide stage, weather conditions, and vehicle performance.

Patrol teams only approached turtles once egg deposition had begun. Carapace morphometrics were determined by both straight-line and over-the-curve measurements (length=CCL, width=CCW). Straight-line measurements were taken with calipers from 1973 until 1990. Since then over-the curve measurements have been taken with a fiberglass measuring tape for convenience. Length was recorded as the distance from the inner nuchal notch to the longest pygal tip. Width was recorded as the widest distance from marginal edge to marginal edge.

Turtles were also surveyed for epibionts during the 1997-2000 seasons. Epibionts were collected using a putty knife and/or pair of stainless steel forceps. Specimens were preserved in either 10% formalin or 70% isopropyl alcohol, sorted and identified. See Frick et al. (1998) for more detailed methodologies regarding epibiont sampling.

Tagging methodology differed from season to season. Four tag types have been interchangeably utilized. Originally, monel metal flipper tags were applied singly to turtles in 1973 and 1974. Nylon "jumbo" rototags were adopted, and used in addition to monel metal tags, from 1975 to 1977. From 1978 to 1986, turtles were triple tagged with either, rototags, monel tags, or Riese (size 2) tags. Inconel (mid-sized) tags were introduced in 1987 and were used exclusively from 1988 to 2000. From 1992 to 2000, Passive Integrated Transponder (PIT) tags were implanted in turtles to supplement double tagging with inconel tags. Infopet and Trovan brand PIT tags and readers were used prior to 1998. Currently, Destron brand PIT tags and readers are used.

Turtles were marked with flipper tags in three fashions. Singly tagged turtles were outfitted with a tag on either the first or second large scale on the posterior edge of the right front flipper. Double-tagged turtles received tags in either the first or second large scale on the posterior edge of each front flipper. Triple tagged turtles received tags on both front flippers and into the first or second large scale on the posterior edge of either the right or left back flipper. All pit tags were implanted subcutaneously just proximal to the center elbow region of the right front flipper. See Figure 2 for tagging locations.

A diagram of the beach profile associated with each encountered turtle crawl was drawn. Diagrams were then compared to specific nesting habitat types as defined by Caldwell (1959) and classified accordingly. Crawls were recorded as either false crawls or nests. Nest protection and relocation did not begin until 1976, during this season all nests (n=50) were relocated into styrofoam coolers. During the 1977-78 seasons all nests were relocated into 5-gallon plastic buckets (n=142 nests). Nests that were placed in 5-gallon buckets were also housed in a roofed shed. From the 1979 season to the present, nests that were considered to be in ideal locations were left *in situ*. Nests that were deemed in danger of tidal inundation were either relocated to areas higher up in the dunes or moved to an open air, self release hatchery, also on the beach. Both *in situ* and relocated nests were protected with galvanized screening to deter animal predation.

Self release hatcheries consisted of a 8 foot x 4 foot wooden frame with attached galvanized sheet metal buried to a depth of ~ 2 feet (Fig. 3). The edges of each buried frame remained slightly exposed ~ 5 inches above the sand surface. An 8-foot x 4-foot

Fig. 2. Tagging locations of external and internal tags on front and rear flippers. Closed circles denote tagging locations for external tags (plastic, monel and inconel). Open circles denote tagging location for internal tags (P.I.T. tags).

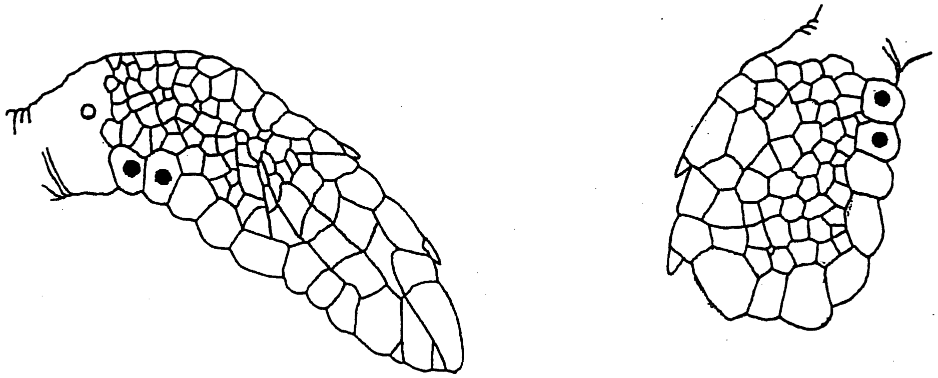
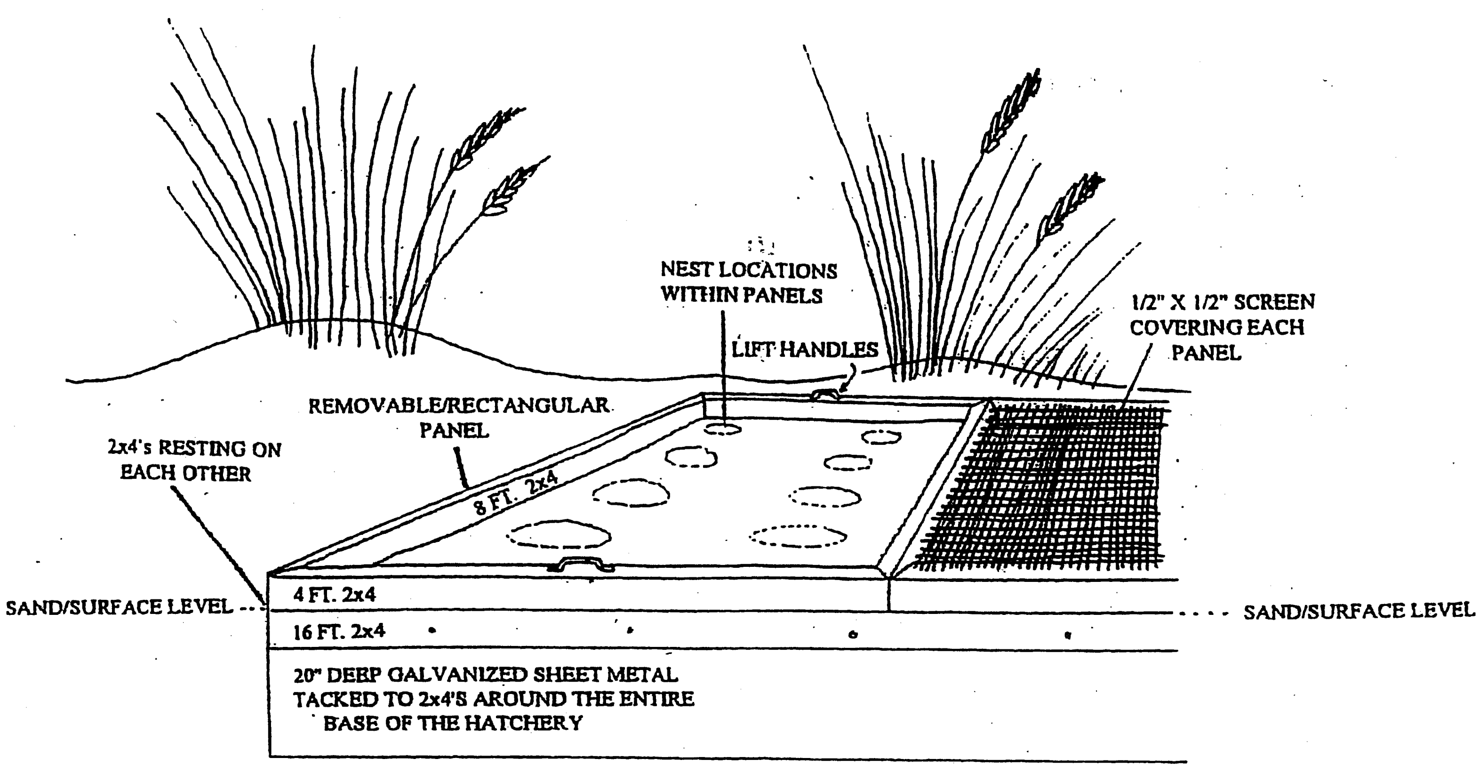


Fig. 3. Diagram of self release hatchery design.



wooden-framed screen (1/2-inch x 1/2-inch mesh size) was used as a cover. Each hatchery held a maximum of 8 nests placed ~ 2 feet apart from each other. The hatchery cover was propped up (~ 4 inches) when nests were due to emerge but otherwise sat flush on top of the buried frame. Due to water build-up within the hatchery after torrential rainstorms, the buried framed was excluded from the hatchery design in 1997. Currently, only the hatchery covers (described above) are used as screened panels for protecting multiple relocated nests. It should be noted that no panels were used during the 2000 season due to the high availability of suitable nesting habitat.

Nests were monitored daily throughout their incubation for signs of predation, erosion, or hatchling activity. Evidence of first hatching was recorded and nests were subsequently exhumed three days after first emergence. Nests that showed no signs of hatching were dug up after 75 days. Nest contents were examined to determine the hatch rate, hatchling survival rate, and the stage of embryological development from unhatched eggs.

Differential Tag Retention

For each observed turtle the condition of previously applied tags was noted and degrading or improperly applied tags were replaced. PIT tags were scanned prior to and after application to test reader and tag performance. Tag loss was documented only from turtles still bearing additional tags. Turtles that only showed tag scars were not used to determine tag loss since scarring can be similar between different tag types. We examined tag retention rates using the following equation from Limpus (1992) and van Dam and Diez (1999):

$$P_i = b_i / (a_i + b_i)$$

where **i** = elapsed time in whole years since tag application:
a_i = number of tags confirmed present on sampled turtles, **i** years since application, and
b_i = number of tags no longer present on sampled turtles, **i** years since application.

The previous equation estimates the probability of tag loss as a time-series. The following equation calculates the standard error of the determined probability (van Dam and Diez, 1999):

$$SE_{pi} = [p_i(1-p_i) / (a_i+b_i)]^{1/2}$$

Equation 2 is with 95 % confidence limits of $p_i = 1.96 \pm SE_{pi}$. Elapsed time in years of tag retention was determined by rounding to the nearest whole year of the actual elapsed time between tag application and tag detection upon subsequent observations.

RESULTS

Section 1: Nesting Habitat Characterization, Composition, and Utilization

1.1. *Tidal Amplitude in Georgia*

The different beach types on Wassaw Island, discussed below, are formed as a result of the tidal influence in these areas. The average tidal amplitude throughout the state is approximately 7 ft., the highest tidal amplitude in the southeastern U.S. However, tides surrounding the new and full moons (spring tides) can have tidal amplitudes of 8-9 ft. Moreover, spring tides associated with strong offshore winds (15-20 m.p.h.) can increase the distance that water is pushed (wash) above the spring tide high tide line by a distance of up to 10 ft. or more. Taking into account the variation in tidal amplitudes that a barrier island can experience over the course of a nesting season, one can imagine the difficulty that exists when deciding whether or not a turtle nest is in danger of tidal inundation. See Figure 4 for a representation of the approximate tidal amplitudes experienced within the varying beach profiles present on Wassaw Island.

1.2. *Habitat Characterization and Tidal Influence on Habitat*

Six distinct dune/beach profiles or types, similar to those described by Caldwell (1959), occur on Wassaw Island (Fig. 4). The dynamic state of Wassaw's beach often produces a gradation from one type to another. The location of each dune/beach type changes from year to year, depending upon the occurrence and frequency of sand shifting storms. As a result, the frequencies at which loggerheads utilize particular latitudes on Wassaw Island also change from season to season, since all six dune types are utilized by loggerheads for nest deposition at varying frequencies (Table 1). Loggerhead dune type preference will be discussed in a Section 1.4. Descriptions of each dune/beach types and how they are affected by tidal influences (adapted from Caldwell 1959; Figure 4) are as follows:

A. *Truncate dunes*: Sharply eroded dunes that back a beach 5-10 feet wide at an average high tide. This dune type is usually eroded further during spring tides and unusually high tides pushed by offshore winds.
B. *Ledge section*: A stretch of dunes having a 0.5-3 foot ledge breaking the middle of its natural slope. This type is formed by the action of wind and tide (undertow).
C. *Wide sloping beach*: Twenty-five to 40 foot wide section of dry sand from the average high tide line to the base (toe) of dunes. If spring tides and accompanying winds are strong enough, this habitat type will become a ledge section (above).
D. *Narrow flat beach*: Ten to 20 foot wide section of dry sand backed by small and separated dunes. The maritime forest is situated closer to the average high tide mark in this area than in other beach type. As a result, dead or dying trees can be found littering the beach anywhere from below the average high tide mark all the way up to the wood line. Spring tides and associated winds will often push the surf closely to the edge of the maritime forest.
E. *Wide flat beach*: Similar to the narrow flat beach but is composed of up to 30-50 feet of dry sand backed by small isolated dunes. Unusually high tides will sometimes push water over the crest of the beach and cause a trough or slough of salt water to form at the base of the small isolated dunes when the tide retreats. Such troughs usually disappear 1-2 hours after high tide.
F. *Barren areas*: Dry, but occasionally inundated, sand stretching 100-400 feet back from the crest of the beach, with only traces of vegetation or low dunes to break their flatness. Shorebirds commonly utilize these dune/beach types for ground nesting. A combination of high wind and spring tides will wash this area with advancing waves approximately 1-2 hours before and after high tide. Some barren areas possess a build-up of sand at the crest of the beach (Fig 4 (F2)), in this type of barren area spring tides will create troughs of water similar to those troughs described for wide beach areas, but much larger.

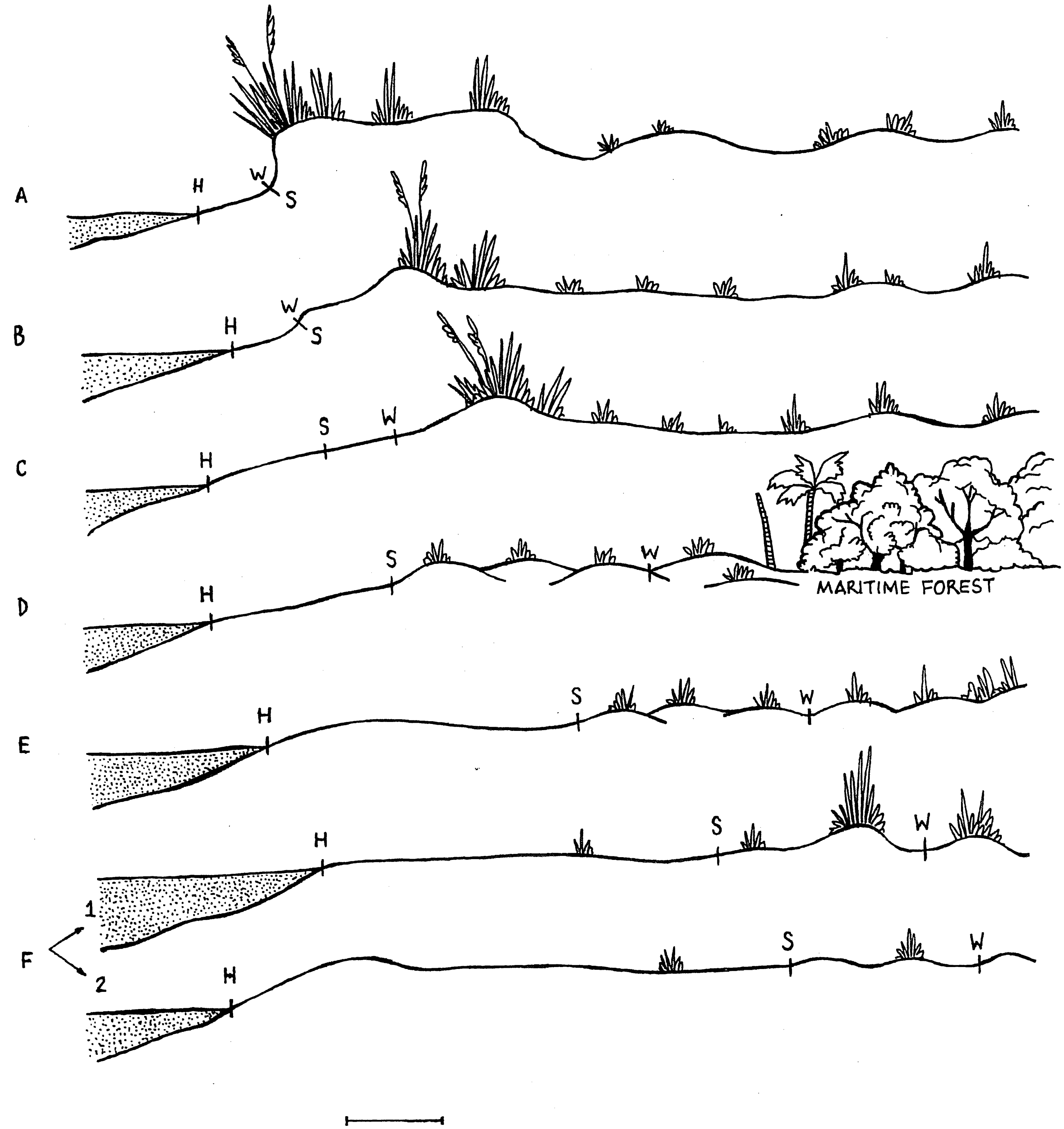


Fig. 4. Profiles of each beach/dune type present on Wassaw Island (adapted from Caldwell, 1959). A= truncate dunes, B= ledge section, C= wide sloping beach, D= narrow flat beach, E= wide flat beach, F (1 and 2)= barren areas (two distinct types), H= average high tide line, S= tidal amplitude during spring tide high tides, W= average distance covered by tidal wash when spring tides are pushed by offshore winds. Scale bar indicates 10 feet. See text (Section 1.2) for descriptions of each beach/dune type.

Table 1. Frequency of crawls observed within each beach/dune type present on Wassaw Island (1980-1990). Refer to text (Section 1.2) and Figure 4 for beach/dune type characterization.

Beach Type	A	B	C	D	E	F	Total No. Crawls (%)
No. False Crawls	156	149	130	97	120	135	787
No. (%) FC Below AHT	2(1)	1(1)	17(13)	3(3)	96(80)	131(97)	250(32)
No. (%) FC Above AHT	0(0)	3(2)	104(80)	93(96)	2(2)	1(1)	203(26)
No. (%) FC @ AHT	154(99)	145(97)	9(7)	1(1)	22(18)	3(2)	334(42)

Table 2. Frequency and location of false crawls with respect to the average high tide line within each beach/dune type present on Wassaw Island (1980-1990). Refer to Section 1.2 and Figure 4.

Beach Type	A	B	C	D	E	F	Total No. Crawls (%)
No. False Crawls	156	149	130	97	120	135	787
No. (%) FC Below AHT	2(1)	1(1)	17(13)	3(3)	96(80)	131(97)	250(32)
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No. (%) FC @ AHT	154(99)	145(97)	9(7)	1(1)	22(18)	3(2)	334(42)

Table 3. Frequency and location of nests deposited within each beach/dune type present on Wassaw Island with respect to the average high tide line (1980-1990). Refer to Section 1.2 and Figure 4.

Beach Type							
No. of Nests	A	B	C	D	E	F	Total No. Crawls (%)
No. (%) Nests Below AHT	44	174	301	65	15	10	609
No. (%) Nests Above AHT	4(9)	2(1)	17(6)	3(5)	0(0)	0(0)	26(4)
No. (%) Nests @ AHT	3(7)	163(94)	272(90)	49(75)	13(87)	10(100)	510(84)
	37(84)	9(5)	12(4)	13(20)	2(13)	0(0)	73(12)

FC=False Crawl
AHT=Average High Tide

1.3. *Habitat Composition*

The sand from Georgia's beaches and dunes are of finer median grain size than those farther north and south (Johnson et al. 1974). The sand on Wassaw Island is comprised primarily of quartz and an uneven mixture off the following minerals: epidote, garnet, hornblende, illmenite, kyanite, leucoxene, monazite, rutile, sillimanite, staurolite, tourmaline and zircon. The principle sources of the aforementioned sand (minerals) on Wassaw Island are the Savannah River watersheds that originate in the Piedmont and mountain areas of the state and the suspended material from the continental shelf adjacent to the island. Although molluscan gravel and calcium carbonate are present, in relatively minute quantities, they are not important contributors to Wassaw's beach sediments (Johnson et al. 1974).

Several types of vegetation can be encountered throughout the loggerhead's nesting habitat on Wassaw Island. This habitat includes areas located in front of the foredune area, the lee slope of the foredune, and herbaceous flats located between the foredune and the maritime forest. The following dune vegetation occurs, in varying frequencies, in these areas: sea oats (*Uniola paniculata*), sea rocket (*Cakile endentula*), beach croton (*Croton punctatus*), beach sand spur (*Cenchrus tribuloides*), salt meadow cord-grass (*Spartina patens*), Russian thistle (*Salsola kali*), sea purslane (*Sesuvium portulacastrum*), beach spurge (*Euphorbia polygonifolia*), seashore elder (*Iva imbricata*), railroad vine (*Ipomoea stolonifera*), beach pennywort (*Hydrocotyle bonariensis*), Spanish bayonet (*Yucca aloifolia*), camphor weed (*Heterotheca subaxillaris*), little blue-stem (*Andropogon scoparius*), prickly pear (*Opuntia humifusa*), hitch-hiker cactus (*Opuntia pusilla*), seaside goldenrod (*Solidago sempervirens*), evening primrose (*Oenothera humifusa*), juniper (*Juniperus virginiana*), yaupon holly (*Ilex vomitoria*), wax myrtle (*Myrica cerifera*), live oak (*Quercus virginiana*), red bay (*Persea borbonia*), cabbage palm (*Sabal palmetto*), saw palmetto (*Serenoa repens*), groundsel bush (*Baccharis halimifolia*) and slash pine (*Pinus elliottii*).

1.4. *Habitat Utilization*

The average number of loggerhead crawls observed on Wassaw Island per year from 1973-2000 is 147 (range = 54 – 287, n=4103 crawls). There is an average of 81 false crawls per year (range = 29-170, n=2256 false crawls) and an average of 66 nests per year (range = 23-135, n=1848 nests). Crawl frequencies in respect to the associated habitat type were determined for all turtle crawls observed during the 1980-1990 nesting seasons. Table 1 presents the frequencies of loggerhead nesting emergences (crawls) within each beach type on Wassaw Island from 1980-1990. Refer to Figure 4 and the description of beach/dunes types discussed above for the following section.

Nesting emergences occur throughout all six beach types depicted in Figure 4. Most emergences occur in beach types A, B and C (Fig 4; Table 1), probably as a result of the slope associated with each type (see Wood and Bjorndal 2000). Also, possibly as a result of respective beach slope, nesting emergences are lower in beach types D, E and F (Fig 4; Table 1).

Although nesting occurs throughout the six beach types, turtles that emerge onto a wide sloping beach are more likely to nest than turtles that emerge into truncate dunes, wide flat beach areas or barren areas (Fig. 4 (A, C, E and F); Table 1). Turtles that emerge into ledge sections (Fig 4 (B); Table 1) have a 54 % chance of nesting, possibly depending upon the height of the ledge or the 'determination' of the emerging turtle.

Turtles emerging into narrow flat beach areas (Fig 4 (D); Table 1) will nest 40 % of the time. On Wassaw Island, narrow flat beaches usually occur where the maritime forest is very close to the average high tide mark. As a result, there are many dead or dying trees (oaks, pines and palms) littering the beach. We have observed many emerging females hit such obstacles and return to the water in this area. Narrow flat beaches containing large amounts of dead wood or beach wood are commonly referred to as 'boneyards' on many of undeveloped barrier islands in the southeastern U.S.

Nesting emergences onto wide flat beaches and into barren areas (Fig 4 (E and F)) often result as false crawls (Table 1). It should be noted that, on Wassaw Island, these areas are associated with offshore sandbars. It is possible that sandbars might inhibit nesting emergence approaches by loggerheads.

Table 2 shows the number of false crawls and where they commonly occur in relation to the average high tide line within each beach type. In truncate dune areas (Fig. 4 (A)) the majority of the false crawls in this area occur at the average high tide line (Table 2). Since the average high tide line usually occurs at the base of the truncate dunes (Fig. 4 (A)), it might be possible to surmise that inaccessibility to higher ground may have contributed greatly to false crawling in this area. We only occasionally see turtles 'carve' out truncate dunes, creating access to higher ground, and subsequently nesting (n=3; Table 3). Instead, the nests laid in this area are usually laid at the average high tide line (Table 3).

Turtles also false crawl regularly at the average high tide mark in ledge section beach types (Fig. 4 (B); Table 2). Ledges form at the average high tide mark as a result of wave action and wind (Fig. 4 (B)). Even though most turtles are capable of traversing a small (6-12 inches high) ledge, it appears that a ledge feature will sometimes cause emerging turtles to false crawl (Table 2). However, the majority (54%) of the turtles that emerge into the ledge section beach type do traverse ledges and deposit nests (Tables 1 and 3).

The wide sloping beach type (Fig. 4 (C)) is utilized for nest deposition more than any other beach type on Wassaw Island (Table 1). Easy access to relatively large dunes probably accounts for the large percentage of nests laid above the average high tide mark in this area (94 %; Table 3). However, most false crawls (80 %) also occur above the average high tide mark in this area (Table 2).

Comments recorded onto our data sheets for particular false crawling events associated with the wide sloping beach often times implicate buried debris as a primary factor for the observed false crawls. That is, turtles begin to either excavate a body pit or dig a nest chamber and encounter immovable debris in the process. We have found buried dock pilings, fluorescent bulbs, 5-gallon buckets, ship's hull pieces, shrimp nets, and bags of tin cans among many other objects buried in the sand where loggerheads have aborted body pits and nests. It should be noted that, within all beach dune types, Wassaw Island nesters perform the stereotyped nesting behavior reported by Margaritoulis (1985) for Greek loggerheads. However, some turtles are observed missing rear flippers. As a results these turtles will attempt to dig nest chambers to no avail and will subsequently false crawl or deposit eggs onto the beach as the turtle returns to the water. Thus, some digging and subsequent false crawling episodes can be attributed to reasons other than buried beach debris.

As discussed above, narrow flat beach areas (Fig. 4 (D)) are often associated with the eroded maritime forest. As a result, dead trees are found at, above and below the average high tide mark in this area. A large number of the false crawls we witness in this area are easily attributed to turtles crawling into downed trees. Yet, fair percentages (40%) of turtles do pass across the 'boneyard' to deposit nests (Table 1), usually above the average high tide mark (75%; Table 3). However, since the maritime forest is in such close proximity to the average high tide mark in this area, nests laid on the narrow flat beach are easily accessible to predators that also forage within the forest. As a result, the nests laid in this area are at risk to a higher diversity of predators than anywhere else on the island. See Section 10 for a list of nest/hatchling predators and their associated beach type foraging area(s).

On Wassaw Island, wide flat beach types (Fig. 4 (E)) are located adjacent to or just southward of offshore sandbars. As a result, high tides push large amounts of sand up into this area. Thus, decreasing the slope of the beach and increasing the distance between the average high tide mark and relatively higher ground. At high tide turtles must traverse 50 feet or more of dry sand before reaching areas that will not be washed by unusually high tides. At low tide turtles sometimes have to crawl up to 100 yards to reach the average high tide mark in this area. From 1980-90, 95% of the nests laid in this area were laid either during mid tide or high tide and 99% of the false crawls observed occurred during mid tide and low tide. Additionally, the percentage of false crawls (89%) observed is much greater than the percentage of nests (11%) that occurred in this beach/dune type area (Table 1). Such information also suggests that as the distance between the water line and the average high tide mark increases so does the chance that a nesting emergence will result in a false crawl.

Barren areas (Fig. 4 (F)) are also associated with offshore sandbars, but more intimately so. On Wassaw Island, these areas represent locations where Cape Charlotte, a sandbar spit located on Wassaw's northeastern-most tip, connects to the island (Fig. 1). This area is very similar in width and slope to the wide flat beach areas described above. Additionally, false crawling and nesting observations are very similar between the two areas (Tables 2 and 3). Most turtles emerge here during high tide when much of the Cape is covered by water. However, on several occasions turtles have emerged and nested at low tide. Consequently, the long crawls apparently tired the turtles to the point where they would not return to the water. Some turtles remained by the nest site for up to twelve hours before research crews had to transport them back to the surf and out of the intense sunlight. Additionally, turtles have crawled into a tidal pond located behind the barren areas (Cape Charlotte) and, apparently disoriented, swam around for several hours before climbing out and onto the bank surrounding the pond. These exhausted turtles also had to be transported back to the surf and out of the morning sun.

Section 2: Morphometrics of Nesting Loggerheads

The most accurate morphometric data collected from Wassaw Island nesters was between 1991-2000. By combining these years, carapace length and width was averaged from 437 measured turtles. The average CCL of Wassaw Island nesters was 100.3 cm (range = 82-120). The average CCW was 91.5 cm (range = 88-110).

Section 3: Population Structure and Rate of Remigration

Using tagging information we classify an individual turtle as either a neophyte, remigrant, immigrant or tag-scarred turtle. A neophyte is a turtle that has not previously been tagged, although she may have nested before. By tagging neophytes we can determine if a turtle is a remigrant or an immigrant. A remigrant is a turtle that has been tagged on Wassaw Island and continues to use Wassaw's beaches during subsequent nesting attempts and nesting seasons. An immigrant is a turtle that was previously tagged on another beach that also utilized Wassaw Island for nest deposition. A tag-scarred turtle is one that has lost all external tags, and only bears tagging scars. A tag-scarred turtle could represent either an immigrant or a remigrant turtle. However, with the introduction of PIT tags in 1992, the number of tag-scarred turtles that cannot be identified as either immigrants or remigrants has begun to decrease. See Section 5 for an analysis of tag retention for turtles tagged on Wassaw Island.

Currently, we have identified 1110 individual loggerhead turtles from Wassaw Island between the 1973-2000 nesting seasons. Each year an average of 46 individual turtles (range = 18 – 69) utilize the island for egg deposition. Neophytes account for 70 % of the turtles observed each year, while remigrants, immigrants, and tag scarred turtles accounted for 10.3%, 7%, and 12.7% of the turtles observed each year, respectively.

Out of the 1110 individual loggerheads identified by our project, 114 individuals have returned to Wassaw Island during subsequent seasons to nest. Seven individuals have a documented nesting history of 10 years or greater. Of the 114 loggerheads that have returned to Wassaw Island, 81 (71.1%) have returned only once, 21 (18.4%) have returned twice, and 12 (10.5%) have returned more than two times (Table 4).

Table 4. Multiple Remigration rates for 33 loggerhead sea turtles on Wassaw National Wildlife Refuge, GA 1974-2000.

INTERVALS (YEARS)	n
2.1	1
2.1.2	1
2.2	4
2.2.2.2.2.2	1
2.2.2.3.2.3	1
2.2.4	1
2.3	4
2.3.2	1
2.4	1
3.2	2
3.2.2	1
3.2.3.3	1
3.3	2
3.3.2.2.3.3	1
3.3.3	2
3.4	1
4.2	2
4.3	1
4.4	1
4.4.3	1
4.5	1
5.3	1
8.2.3.2.2	1

Excluding neophytes tagged during the 2000-nesting season (since they could not remigrate within a season), a Type I remigration rate was used to measure the remigration activity per turtle within our study area. A Type 1 remigration rate is defined as the ratio of the number of remigation records to the total number of individuals marked (Richardson et al., 1978). Applying this definition to Wassaw Island turtles, we find an 10.3% (114/1110) remigration rate.

Several points must be taken in to account when determining a rate of remigration for turtles that nest within Barrier Island sequences. For instance, while we only consider a turtle as a remigrant when she returns to nest at the study site where she was originally tagged, a broader definition of remigration might include beaches surrounding or within close proximity to the original saturation tagging study site. Since the islands adjacent to Wassaw Island are not patrolled at night, the remigration rate for nesters may be considerably higher. Additionally, Georgia's barrier islands are very dynamic environments and seasonal storms may drastically change the condition of any island's beaches from one nesting season to another. As a result, loggerheads will shift their nesting concentrations from island to island. Point being, until saturation tagging is supplemented by additional coverage on beaches surrounding the study site, it is not possible to maximize the amount of information that can be accumulated by tagging nesting sea turtles.

Section 4: Tag Returns and Recoveries

In this section we are differentiating between the terms 'tag return' and 'tag recovery' to imply the origin of the tags placed upon the observed loggerheads. For instance, a 'tag return' is locality/migration information from a turtle that was originally tagged on Wassaw Island but was observed in a locality other than Wassaw Island. A 'tag recovery' is locality/migration information from a turtle that CRP staff observed nesting on Wassaw Island but was originally tagged elsewhere.

4.1. *Tag Returns*

From 1973 through 2000, the Caretta Research Project has tagged 1110 loggerhead turtles. We have received 107 tag returns (9.6 % tag return rate) from 99 individual turtles. These returns come from three sources: females encountered nesting or crawling on other nesting beaches (74.8%, n=80), turtles captured in shrimp trawlers (18.7%, n=20) and turtles reported dead on the beach (6.5%, n=7). The distribution, distances and dates of tag returns appear in Table 5 and Figure 5.

Of the 80 turtles found crawling or nesting on other beaches, 22 (27.5%) were found north of Wassaw Island and 58 (72.5%) were found south of Wassaw Island. The distances of nesting beaches also utilized by loggerheads observed on Wassaw Island range from <125 km - 410 km away (Fig. 5; Table 5). The furthest north we have had a nesting tag return was from Onslow Beach, NC (400 km) and the furthest south was from Cape Canaveral National Seashore, Florida (410 km; Fig. 5; Table 5).

Commercial shrimp trawlers have also provided tag returns (n=20). Five (25%) turtles were captured north of Wassaw Island, 12 (60%) were captured south of Wassaw Island, two (10 %) were captured in waters adjacent to Wassaw Island and one (5%) was captured from an unknown location (Fig. 5; Table 5). The distances recorded for turtles captured in shrimp trawls that were originally tagged on Wassaw Island range from <125 km - >1935 km away (Fig. 5; Table 5). The farthest migratory distance/location recorded for a turtle originally tagged as a nester on Wassaw Island was a turtle that was recaptured 14 months later in a trawler off Gulf Shores, Alabama, in the Gulf of Mexico (~1935 km; Fig. 5; Table 5).

Seven tag returns (7 %) were reported from turtles that washed up dead on various beaches. The distances recorded for turtles originally tagged on Wassaw Island that washed up dead on beaches elsewhere range from <125 km – 980 km away (Fig 5; Table 5). The furthest distance indicated above represents a tag return from Fenwick Island, Delaware (Fig 5; Table 5).

Refer to Table 5 for the dates associated with each tag return. The longest interval between the date a loggerhead was tagged on Wassaw Island and the date the turtle was recovered again was 7 years. This turtle was tagged on Wassaw Island in 1987 and then she was seen nesting on Ossabaw Island, Georgia in 1994. There were also two returns reported to us 6 years after the turtles were originally tagged on Wassaw Island; one from Blackbeard Island, Georgia and one from Hilton Head Island, South Carolina (Fig 5; Table 5).

4.2. *Tag Recoveries*

From 1973-2000, the Caretta Research Project has identified 57 turtles crawling or nesting on Wassaw Island that were originally tagged elsewhere (immigrant turtles). See Figure 5 and Table 6 for the tagging origins of immigrant turtles that have been observed on Wassaw Island. Fifty-six of the observed immigrants were originally tagged as nesters on other beaches. One immigrant was tagged after being caught in a pound net in Chesapeake Bay, Virginia. The majority of immigrants (91.2%, n=52) have come from beaches south of Wassaw Island, while only 8.8% (n=5) have come from northerly beaches. Fifty-three (93.0%) were originally tagged on beaches within 125 km of Wassaw Island.

Table 5. Distribution, Distances and Dates of Tag Returns from Wassaw Island, GA 1973-2000.

Return #	Source of Return	Date Originally Tagged	Date of Return	Minimum Distance Traveled (km)	Return Location
1	NE	June 8, 1973	1973	40	Hilton Head Island, SC
2	TRAWL	June 10, 1973	July 5, 1973	-	Wassaw Sound, GA
3	NE	June 10, 1973	July 19, 1973	10	Little Tybee Island, GA
4	TRAWL	June 15, 1973	1973	-	Wassaw Sound, GA
5	DOB	June 17, 1973	1973	14	Ossabaw Island, GA
6	NE	June 3, 1974	1974	14	Ossabaw Island, GA
7	NE	June 4, 1974	August, 1974	?	Unknown
8	TRAWL	June 5, 1974	July, 1974	55	Off of Sapelo Island, GA
9	NE	June 5, 1974	1974	14	Ossabaw Island, GA
10	NE	June 8, 1974	1974	14	Ossabaw Island, GA
11	NE	June 12, 1974	1974	14	Ossabaw Island, GA
12	TRAWL	June 19, 1975	July 13, 1975	?	Unknown
13	TRAWL	June 20, 1975	January 24, 1977	410	Cape Canaveral, FL
14	TRAWL	July 1, 1975	May 27, 1983	55	Off of Sapelo Island, GA
15	NE	May 25, 1976	1979	48	Blackbeard Island, GA
16	NE	May 27, 1976	1976	110	Little Cumberland Island, GA
17	TRAWL	June 4, 1976	June 5, 1980	55	Off of Sapelo Island, GA
18	NE	June 5, 1976	1976	110	Little Cumberland Island, GA
19	NE	July 5, 1976	1976, 1979, 1980	118	Little Cumberland and Cumberland Islands, GA
20	NE	June 16, 1977	1977	103	Jekyll Island, GA
21	NE	June 27, 1977	1977	14	Ossabaw Island, GA
22	NE	June 30, 1977	1977	118	Cumberland Island, GA
23	NE	July 3, 1977	1979	48	Blackbeard Island, GA
24	NE	June 2, 1978	1978	14	Ossabaw Island, GA
25	NE	June 10, 1978	1981	48	Blackbeard Island, GA
26	NE	June 15, 1978	1978	410	Cape Canaveral, FL
27	NE	June 16, 1978	1978	335	Ocean Isle, NC
28	NE	June 30, 1978	1978	14	Ossabaw Island, GA
29	NE	June 30, 1978	1984	12	Cabbage Island, GA
30	NE	July 1, 1978	1978	48	Blackbeard Island, GA
31	Trawl/DOB	July 17, 1978	Aug. 3/Aug 7/78	14	Ossabaw Sound/Green Island, GA
32	NE	May 27, 1979	1979	48	Blackbeard Island, GA
33	NE	May 29, 1979	1979	48	Ossabaw & Blackbeard Islands, GA
34	NE/DOB	May 29, 1979	1979/Aug 15 1982	48	Blackbeard Island/Hilton Head Island, GA
35	TRAWL	June 3, 1979	1980	12	Off of Tybee Island, GA
36	NE	June 4, 1979	1979	14	Ossabaw Island, GA
37	NE	June 7, 1979	1979	14	Ossabaw Island, GA
38	NE	June 10, 1979	1979	14	Ossabaw Island, GA
39	TRAWL	June 27, 1979	1980	50	Sapelo Sea Buoy, GA
40	NE	June 28, 1979	1979	14	Ossabaw Island, GA
41	NE	July 10, 1979	1983	48	Blackbeard Island, GA
42	NE	May 26, 1980	1980	14	Ossabaw Island, GA
43	Tag Ret.	May 28, 1980	November, 1982	700	Nag's Head, NC
44	NE	June 1, 1980	1980	14	Ossabaw Island, GA
45	?	June 2, 1980		27	Colonel's Island, GA
46	DOB	June 10, 1980	July 26, 1980	19	Cape Romaine Seashore, SC
47	NE	June 13	1980	14	Ossabaw Island, GA
48	NE	June 22	1980	48	Blackbeard Island, GA
49	TRAWL	June 22, 1980	September 14, 1983	860	Off of Hog Island, VA
50	NE	June 26, 1980	1980	48	Blackbeard Island, GA
51	TRAWL	July 3, 1980	August 28, 1980	118	Off of Cumberland Island, GA

52	NE	May 26, 1981	1981	70	Fripp Island, SC
53	NE	May 29, 1981	1981	48	Blackbeard Island, GA
54	NE	May 30, 1981	1981	48	Blackbeard Island, GA
55	TRAWL	June 6, 1981	July 31, 1983	825	Smith Island, VA
56	NE	June 6, 1981	1981	10	Little Tybee, GA
57	TRAWL	July 3, 1981	March 17, 1982	410	Cape Canaveral, FL
58	NE	July 10, 1981	1984	110	Little Cumberland Island, GA
59	TRAWL	July 10, 1981	3/7 & 10/30 1982	325	Diamond Shoals, NC / St. Andrew's Sound, GA
60	NE	July 10, 1981	1981	140	Fernandina Beach, FL
61	TRAWL	June 20, 1982	June 24, 1982	27	Off of St. Catherine's Island, GA
62	NE	June 21, 1982	1982	93	Edisto Beach, SC
63	TRAWL	June 23, 1982	September 2, 1983	1935	Gulf Shores, AL
64	DOB	June 28, 1982	July 1, 1982	40	Hilton Head Island, SC
65	NE	May 27, 1983	1983	150	Little Talbot Island, FL
66	NE	June 7, 1983	1983	118	Cumberland Island, GA
67	NE	July 10, 1983	1983	48	Blackbeard Island, GA
68	TRAWL	June 21, 1983	July 20, 1983	215	Georgetown, SC
69	TRAWL	June 13, 1984	June 27, 1984	27	Off of St. Catherine's Island, GA
70	NE	June 25, 1984	1989	118	Cumberland Island, GA
71	NE	July 2, 1984	1984	110	Little Cumberland and Jekyll Islands, GA
72	NE	June 16, 1987	1994	14	Ossabaw Island, GA
73	NE	July 22, 1988	1994	48	Blackbeard Island, GA
74	NE	July 29, 1988	1991	10	Little Tybee Island, GA
75	NE	June 21, 1989	1994	48	Blackbeard Island, GA
76	DOB	May 28, 1990	1990	410	Cape Canaveral, FL
77	NE	May 29, 1990	1993	48	Blackbeard Island, GA
78	DOB	June 8, 1990	July 26, 1993	980	Fenwick Island, DE
79	NE	June 15, 1990	1992/1998	82	St. Simon's / Ossabaw Islands, GA
80	NE	May 24, 1991	1991	50	Sapelo Island, GA
81	NE	June 16, 1991	1994	27	St. Catherine's Island, GA
82	NE	June 21, 1991	1991	10	Little Tybee Island, GA
83	NE	June 28, 1992	1992	82	St. Simon's Island, GA
84	NE	June 30, 1992	1992	82	St. Simon's Island, GA
85	NE	July 23, 1992	1996	40	Hilton Head Island, GA
86	NE	July 3, 1993	1999	40	Hilton Head Island, GA
87	NE	May 25, 1994	1994	93	Edisto Island, SC
88	NE	June 9, 1994	1994	63	Hunting and Pritchard's Islands, SC
89	NE	July 5, 1994	1994	14	Ossabaw Island, GA
90	NE	June 1, 1995	1998	48	Blackbeard Island, GA
91	NE	June 20, 1996	1996	40	Hilton Head Island, SC
92	NE	June 28, 1996	1996	370	Bald Head Island, NC
93	DOB	July 4, 1996		40	South Carolina
94	NE	June 14, 1998	1998	110	Little Cumberland Island, GA
95	NE	June 15, 1998	1998	93	Edisto Island, SC
96	NE	May 30, 1999	1999	130	Folly Beach, SC
97	NE	June 6, 1999	1999	400	Onslow Beach, NC
98	NE	June 21, 1994	June 9, 2000	130	Folly Beach, SC
99	NE	May 29, 2000	June 17, 2000	40	Hilton Head Island, SC
100	NE	June 21, 1991	July 7, 2000	50	Sapelo Island, GA

Table 6. Distribution, Distances and Dates of Tags Recovered on Wassaw Island, GA 1973-2000.

Recovery #	Tag Origin	Date Originally Tagged	Date of Recovery	Minimum Distance Traveled (km)
1	Little Cumberland Island, GA	1972	June 3, 1974	110
2	Jekyll Island, GA	1973	July 9, 1975	103
3	Kiawah Island, SC	1975	May 24, 1978	123
4	Little Cumberland Island, GA	1975	June 15, 1981	110
5	Ossabaw Island, GA	1978	July 8, 1978	14
6	Little Cumberland Island, GA	1978	July 15, 1978	110
7	Little Cumberland Island, GA	1978	July 20, 1978	110
8	Ossabaw Island, GA	1979	June 17, 1979	14
9	Ossabaw Island, GA	1979	June 19, 1979	14
10	Ossabaw Island, GA	1979	June 25, 1979	14
11	Ossabaw Island, GA	1979	June 28, 1979	14
12	Little Cumberland Island, GA	1975	July 12, 1979	110
13	Jekyll Island, GA	1979	July 14, 1979	103
14	Ossabaw Island, GA	1979	July 16, 1979	14
15	Ossabaw Island, GA	1979	July 25, 1979	14
16	Ossabaw Island, GA	1980	July 17, 1980	14
17	Ossabaw Island, GA	1980	July 24, 1980	14
18	Ossabaw Island, GA	1978	May 27, 1981	14
19	Little Cumberland Island, GA	1978	June 5, 1981	110
20	Little Cumberland Island, GA	1978	June 14. 1981	110
21	Ossabaw Island, GA	1978	June 16, 1981	14
22	Little Cumberland Island, GA	1979	June 20, 1981	110
23	Ossabaw Island, GA	1979	June 22, 1981	14
24	Cumberland Island, GA	1974	July 20, 1981	118
25	Cape Canaveral, FL	1982	May 27, 1982	410
26	Ossabaw Island, GA	1979	June 23, 1982	14
27	Little Cumberland Island, GA	1982	June 30, 1982	110
28	Ossabaw Island, GA	1980	June 7, 1983	14
29	Cumberland Island, GA	1983	June 17, 1983	118
30	Little Cumberland Island, GA	1974	June 23, 1983	110
31	Little Cumberland Island, GA	1980	July 6, 1983	110
32	Jekyll Island, GA	1981	July 26, 1984	103
33	Cumberland Island, GA	1982	June 9, 1985	118
34	Cumberland Island, GA	1979	June 17, 1985	118
35	Jekyll Island, GA	1982	June 22, 1985	103
36	Little Cumberland Island, GA	1982	June 27, 1985	110
37	Cumberland Island, GA	1985	July 25, 1985	118
38	Ossabaw Island, GA	1978	July 28, 1985	14
39	Cumberland Island, GA	1983	June 26, 1986	118
40	Jekyll Island, GA	1983	July 12, 1988	103
41	Hilton Head, SC	1989	July 1, 1989	40
42	Hilton Head, SC	1989	July 2, 1989	40
43	Cumberland Island, GA	1989	July 3, 1989	118
44	Little Cumberland Island, GA	1985	July 31, 1989	110
45	Jekyll Island, GA	1985	May 23, 1990	103
46	Cumberland Island, GA	1983	June 9, 1990	118
47	Jekyll Island, GA	1982	July 15, 1990	103
48	Cumberland Island, GA	1988	June 23, 1991	118
49	Jekyll Island, GA	1992	July 27, 1992	103
50	Chesapeake Bay, VA (pound net capture)	1989	June 4, 1994	801
51	Little Cumberland Island, GA	1990	July 7, 1994	110
52	Cumberland Island, GA	1991	July 14, 1994	118
53	Jekyll Island, GA	1996	June 28, 1996	103
54	Little Cumberland Island, GA	1994	July 16, 1996 and July 17, 2000	110
55	Jekyll Island, GA	1995	June 17, 1998	103
56	Jekyll Island, GA	1997	May 24, 1999	103
57	Little Cumberland Island, GA	June 25, 2000	July 5, 2000	110

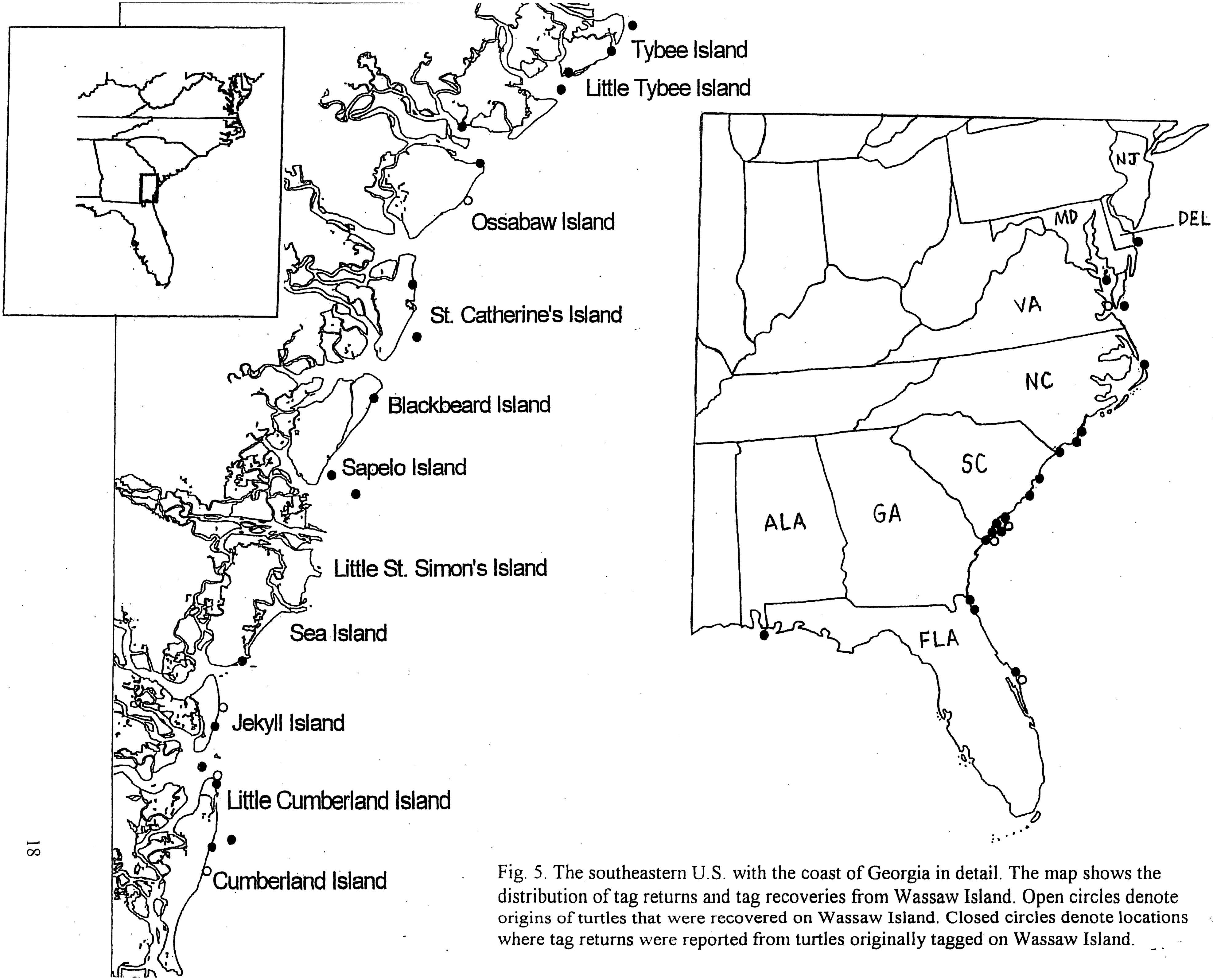

Fig. 5. The southeastern U.S. with the coast of Georgia in detail. The map shows the distribution of tag returns and tag recoveries from Wassaw Island. Open circles denote origins of turtles that were recovered on Wassaw Island. Closed circles denote locations where tag returns were reported from turtles originally tagged on Wassaw Island.

Section 5: Differential Tag Retention

From 1973 through 2000, 114 individual turtles were tagged and subsequently 'recaptured' on Wassaw Island. A total of 350 tags were placed on these turtles and 183 tags were confirmed as lost. Figure 6 depicts the probability of tag retention for plastic, inconel, and PIT tags. Figure 7 and Table 7 summarize the tag data for each tag type applied. Due to similarities in size, style, and application of both the Roto and Riese plastic tags, we have combined both tag types into the same data set and collectively refer to the two types simply as 'plastic' tags herein.

5.1. *External Tags*

Of the three external tags used to mark loggerheads on Wassaw Island (monel alloy, inconel and plastic), plastic tags placed on the hind flippers had the highest retention rates in the 25 year period since they were applied to turtles (1975-2000; Table 7; Fig. 6; 50%-80% chance of remaining on the flippers). For example, one loggerhead tagged on Wassaw Island in 1980 was found nesting on Ossabaw Island, a neighboring island, in 1999 still possessing her original plastic tags on her rear flippers. As can be seen in Table 7 and Figure 6, the probability of plastic tags remaining on the front flippers steadily decreases over time and at a faster rate than observed for plastic tags applied to the rear flippers.

Some plastic tags that had numbers imprinted on them rather shallowly became abraded and unreadable. These tags had to be removed. However, several abraded and unreadable tags were brought over to the Savannah Police Department's Forensic Sciences Lab and electron microscopy and other forensic techniques were used to identify the tag numbers. Over time, plastic tags have become rigid and quite brittle. As a result, the identification number bearing tabs have fallen off or been broken off by the turtle. However, plastic plugs left behind in the turtle's flippers still mark the animal as a 'cohort' of the marked population.

Inconel tags had no greater than a 50% chance of remaining attached to the front flippers over the 12 year period of time since we began double tagging with this tag type (1988-2000; Table 7; Figs 6 and 7). However, one inconel tag has remained upon the front flipper of a turtle for an 11-year period. As monel tags were only applied singly during 1973 and 1974 and were only used sporadically after that until 1977, only eleven monel tags have been recovered. As a result, the information we provide on monel tag retention is less complete than desired and appears in Table 7 and Figure 7. One monel tag was retained by a turtle for 7 years.

5.2. *Internal Tags (PIT tags)*

Thirty-two turtles implanted with PIT tags were recaptured over an eight-year period (1992-2000). Eight PIT tags (25%) were either lost or unreadable (Table 7; Fig. 7). Since we routinely scan the entire flipper it is unlikely that PIT tags have migrated from the elbow region of the turtle to the shoulder or the tip of the flipper. However, it is possible that migration has occurred outside of the scanning range and into other areas on the turtle, but this too seems highly unlikely. Instead, we believe some PIT tags were missed or unreadable due to the variety of PIT tag and scanner brands that have been used by our project since PIT tagging began in 1992. Apparently, the Infopet and Trovan brand scanners that were used simultaneously in some seasons were not entirely

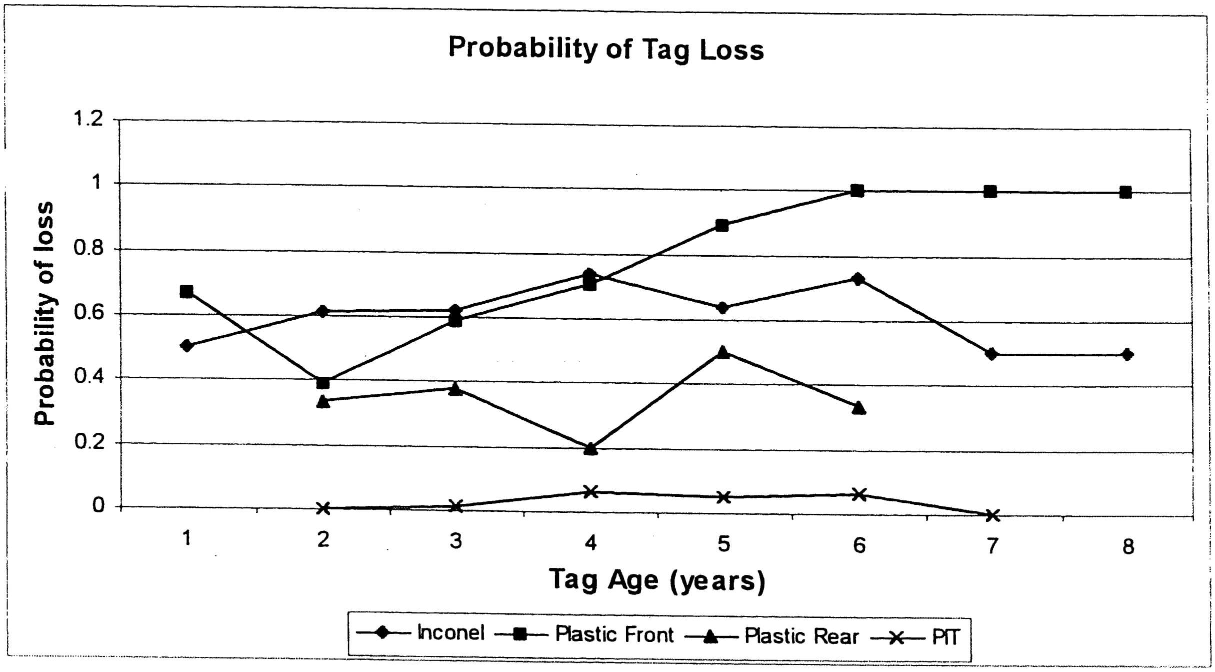

Figure 6. Probability of tag retention for inconel, plastic (placed on the front and back flippers) and PIT tags placed on loggerhead sea turtles on Wassaw National Wildlife Refuge, GA 1973-2000.

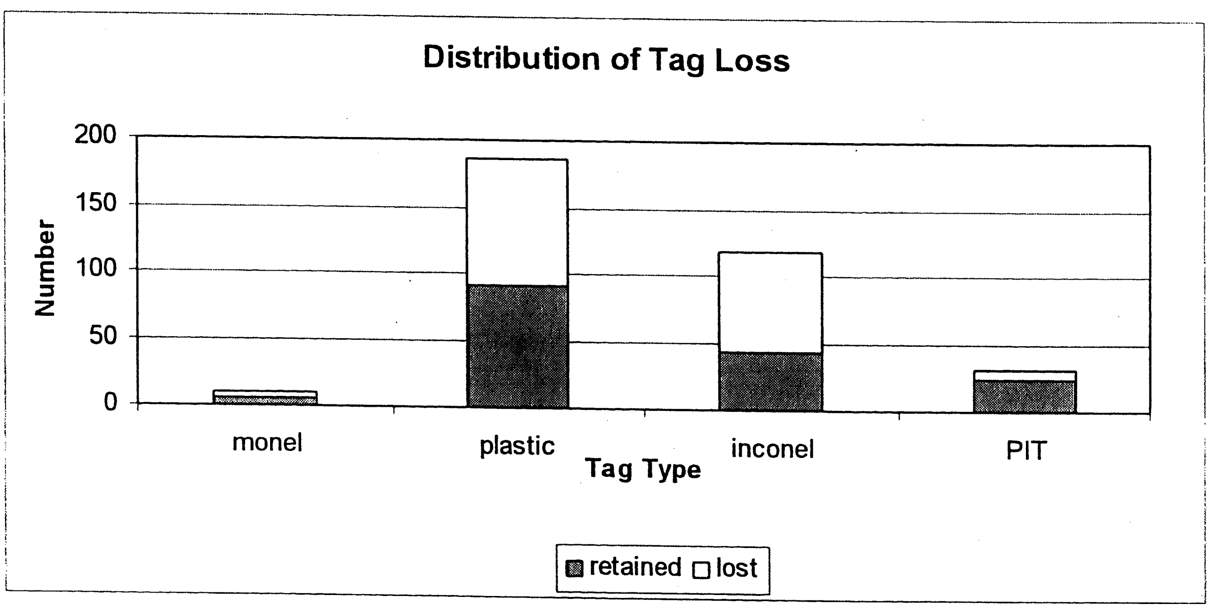

Figure 7. Comparison of tag retention and loss for monel, plastic, inconel, and PIT tags placed on loggerhead sea turtles on Wassaw National Wildlife Refuge, GA 1973-2000.

Table 7. Probability of Tag Retention for each of the four tag types.

Tag Type and Location	Years Since Appplicatio n (I)	Tags Confirmed-Present	Tags Confirmed-Lost	Total	Pi (Probability of tag loss)	SEpi	95% Confidence Intervals
MONEL:							
Front:	2	3	3	6	.500	.04	+-.400
	3	2	1	3	.333	.07	+-.533
	7	0	1	1	1.00		
Rear:	2	1	0	1	0.00		
PLASTIC:							
Front:	1	1	2	3	.667	.07	+-.533
	2	30	19	49	.388	0	+-.136
	3	16	23	39	.590	.01	+-.154
	4	7	17	24	.708	.01	+-.182
	5	1	8	9	.889	.01	+-.205
	6	0	3	3	1.00	0	
	7	0	2	2	1.00	0	
	8	0	2	2	1.00	0	
Rear:	1	0	1	1	1.00	0	
	2	12	6	18	.333	.01	+-.218
	3	10	6	16	.375	.01	+-.237
	4	8	2	10	.200	.02	+-.248
	5	2	2	4	.5	.06	+-.49
	6	2	1	3	.33	.07	+-.533
	8	1	0	1	0		
	9	0	1	1	1.0	0	
	19	1	0	1	0		
INCONEL:							
Front:	1	1	1	2	.5	.125	+-.693
	2	10	16	26	.615	.009	+-.187
	3	16	26	42	.619	.006	+-.147
	4	4	11	15	.733	.013	+-.224
	5	4	7	11	.636	.021	+-.284
	6	3	8	11	.727	.018	+-.263
	7	2	2	4	.500	.063	+-.490
	8	3	3	6	.500	.042	+-.400
	11	1	0	1	0		
Rear:	2	1	0	1	0		
	8	0	1	1	1.00		
	9	1	0	1	0		
PIT TAGS:							
Front:	1	1	0	1	0		
	2	3	0	3	0		
	3	11	3	14	.214	.02	+-.215
	4	2	2	4	.500	.063	+-.490
	5	3	1	4	.250	.047	0.00
	6	2	2	4	.500	.063	+-.49
	7	1	0	1	0.00		
	8	1	0	1	0.00		

compatible. Not until we acquired a Destron brand universal reader did we realize that turtles that were implanted with Trovan brand PIT tags were not readable to Infopet brand readers (universal readers are those can detect any type of PIT tag currently on the market). As a result, some turtles have both Trovan and Infopet brand tags implanted in the same flipper. Since we now use only Destron brand tags and scanners it is possible that the retention rates observed for PIT tagged turtles on Wassaw Island may increase as the turtles return to nest and are scanned for internal tags using more reliable equipment.

Section 6: Remigration and Internesting Intervals

The average remigration interval (179 observations from n=114 individuals) observed for Wassaw Island remigrants is 3.15 years between nesting seasons (range = 1-8 years). Using data collected from 1995-2000, since these years represent seasons where over 90% of the turtles nesting on Wassaw Island were observed within each season, the average observed internesting interval is 17.4 days between successive nests (range=10-52 days; n=93 turtles). However, it should be noted that since turtles are missed during nightly patrols and beaches adjacent to Wassaw Island are not monitored every night, the aforementioned intervals might not represent the actual intervals that are occurring.

Section 7: Fecundity

Nest sizes ranged between 1 to 196 eggs per clutch and averaged 116.4 eggs/nest (n = 1848 nests from 1973-2000). Since tagging began on Wassaw Island in 1973, loggerheads encountered during subsequent nesting observations have deposited an average of 2.89 nests per season (n= 294 turtles; range=1-6 nests per turtle). Yet, since turtles will migrate to other nesting areas within the same season and some turtles are missed during nightly patrols, it is very possible that the average number of nests laid within a season by an individual turtle could be greater than that presented above. Supplemental research would help to clarify the reproductive potential of Wassaw Island's loggerhead turtles (i.e. ultrasonography).

Section 8: Description, Morphometrics and Mass of Eggs and Hatchlings

8.1. *Hatchling Description, Morphometrics and Mass*

There is a considerable range of coloration from the hatchlings observed from Wassaw Island, even within the same clutch. Most hatchlings appear gray dorsally to light cream ventrally. Some hatchlings are dark brown to almost black dorsally and ventrally. Lighter colored hatchlings are reddish-chestnut brown to tan, dorsally. Occasionally albino specimens are observed. A few of the observed albinos had pink eyes but most have either brown or blue eyes. A single nest in 1995 contained 11 snow-white hatchlings with blue eyes. All of the aforementioned hatchlings appeared relatively healthy. Four of these turtles were raised in captivity and subsequently released four years later in good condition.

The morphometrics and mass of 110 hatchlings from seven different nests were recorded. Morphometrics were recorded in mm using Vernier calipers. Straight carapace length (SCL) was determined by measuring from the nuchal notch to the division between the post-central scales. Straight carapace width (SCW) was determined by measuring the widest portion of the hatchling carapace from marginal edge to marginal edge. Depth was determined by measuring the highest profile of the hatchling carapace. The average morphometrics recorded were SCL= 44.5 mm (range = 40.4 mm – 47.1 mm), SCW= 33.8 mm (range = 28.2 mm – 36.9 mm), depth = 19.1 mm (range = 16.3 mm – 21.0 mm). Hatchling mass was determined using a spring scale and read to an accuracy of 0.1 g. The average mass observed from Wassaw Island hatchlings was 18.4 g (range = 14.0 g – 23.0 g).

8.2. *Size and Mass of Eggs*

We recorded the size and weight of 298 loggerhead eggs from 15 different nests during the 2000 season. Mass was determined using a spring scale read to an accuracy of 0.1 g. The size or diameter of each egg was determined by measuring the greatest diameter using calipers. All sand was wiped clean from eggs using a small brush. The average egg mass recorded was 36.2 g (range = 26.0 g –47.0 g.). The average greatest egg diameter recorded was 41.3 mm (range = 37.2 mm – 43.9 mm).

Occasionally turtles will lay small (15-25 mm greatest diameter) yolkless eggs within a nest containing other eggs of 'normal' size. Loggerheads will also lay highly deformed eggs, which appear to consist of several eggs fused together via the shell or by long calcium 'streamers'. One turtle, in 1995, laid 35 eggs and a large deformed egg mass (as described above) that filled ~ 2/3 of the entire nest chamber. These deformed eggs also lack yolks and occur rather infrequently.

Section 9: Hatch Rates and Hatchling Emergence Success

9.1. *Hatch Rates*

By combining hatching data from 1973 to 2000, the average hatch rate (# of hatched eggs divided by the total # of eggs in the nest x 100 = percent hatched or hatch rate) observed from nests deposited on Wassaw Island is 59.2% (n=1848 nests). It should be noted that the average hatch rate for the first three seasons of the program (1973-1975), before nests were relocated or protected with galvanized screening, was 0.00% (n=152 nests). By averaging the hatch rates for only the seasons where there was nest protection and relocation (1976-2000), the observed average hatch rate is 67.0% (n=1696 nests). All nests from the 1976 season (n=50) were stored in styrofoam coolers, the average hatch rate for these nests was 27.0%. From 1977 to 1978, all nests (n=142) were incubated in 5-gallon buckets stored beneath a roofed shed. The average hatch rate for these nests was 35.7%. The average hatch rate for nests deposited during the 1979-2000 seasons (relocated and *in situ*; n=1656), which were nests incubated on the beach, was 71.4 %.

With the exception of 121 nests that were not recorded as being either left *in situ* or relocated, we compared the hatch rates between nests left *in situ* and those that were relocated from their original site of deposition (includes nests relocated to open-air, self-release hatcheries and to safe zones or higher areas in the dunes) for the 1979-2000 seasons (n=1535 nests). The average hatch rate for *in situ* nests (n=220) was 47.9 %. Relocated nests (n=1315) had an average hatch rate of 70.5%. However, any comparisons made between relocated and *in situ* nests on Wassaw Island should be generated carefully as the same criteria used to determine if a nest can be left *in situ* are the same criteria used when determining where to relocate a nest or place a self-release hatchery. Additionally, there were many more nests relocated than left *in situ*.

9.2. *Emergence Success*

Although hatch rates are useful for assessing the results of the incubation period experienced by nests, they do not accurately represent the percentage of the hatchlings actually emerging into the outside environment. Therefore, it becomes important to determine the emergence success experienced from any given nest. Emergence success represents the percentage of all the hatchlings produced in a nest that successfully exited the nest chamber, thus the emergence success does not include dead hatchlings located in the nest. The emergence success of a nest is determined by subtracting the number of dead and live hatchlings encountered in a nest from the number of hatched eggs, the difference is then divided by the total number of eggs originally deposited within the nest and multiplied by 100. The average emergence success for nests deposited from 1973-2000 (n=1848 nests) was 57.3 %. Excluding the first three seasons (1973-1975), since all nests (n= 152) had a 0.00 % hatch rate due to predation and/or tidal inundation, the average emergence success rate for the 1976-2000 seasons (n=1696 nests) was 64.0 %. The average emergence success rate for nests incubated in styrofoam coolers (1976, n=50 nests) was 10.8 %. Average emergence success for nests incubated in 5-gallon buckets (1977-78, n=142 nests) was 34.5 %. Averaging the emergence success for all nests (n= 1656) incubated on the beach (relocated and *in situ*; 1979-2000), the rate was 69.1 %. From 1979-2000, *in situ* (n= 220) and relocated nests (n= 1313) had average emergence success rates of 45.7 % and 68.4 %, respectively.

Section 10: Predators of Loggerhead Nests and Hatchlings

A variety of vertebrates and invertebrates utilize the loggerhead's nesting habitat as foraging grounds on Wassaw Island. Ghost crabs (*Ocypode quadrata*), fire ants (*Solenopsis invicta* and *S. globularia littoralis*) and raccoons (*Procycon lotor*) are predators of nests and emerging hatchlings in all six beach types discussed in Section 1 (Fig 4). Great horned owls (*Bubo virginianus*) and screech owls (*Otus asio*) have only been observed feeding on hatchlings in narrow flat beach areas. Apparently, the close proximity of the maritime forest to the average high tide mark in this area provides these avian predators with the appropriate foraging habitat, which allows them to perch and scan for emerging hatchlings. Another predator only observed from narrow flat beach areas is the yellow rat snake (*Elaphe obsoleta quadrivittata*). On one occasion, a rat snake was found consuming a single egg from a loggerhead nest. The snake had entered the nest via a ghost crab hole.

Minks (*Mustela vison*) can be found foraging in narrow flat beach and wide flat beach areas where they will dig underneath protective screening and consume loggerhead eggs. Hogs or European wild boars (*Sus scrofa*) are only rarely observed as predators of both nests and emerging hatchlings, possibly due to their low numbers on the island. Instances of hog predation have occurred in narrow flat beach areas and wide flat beach areas. Another documented predator was an unidentified seagull that was seen consuming hatchlings in a wide flat beach area during a daytime emergence apparently induced by heavy rains. A scarlet snake (*Cemophora coccinea*) was found in a hatched nest, located in a narrow flat beach area, but was not seen consuming any unhatched eggs. Like the aforementioned rat snake, the scarlet snake apparently entered the nest via a ghost crab hole.

Section 11: Epibiont Information

Eighty epibiotic species have been recorded as commensals or parasites of nesting loggerheads on Wassaw Island between 1997-2000 (Table 8). See Frick et al. (1998) for additional epibionts recorded from nesting loggerheads elsewhere along the Georgia coast. Frick et al. (in press) use epibiont data to suggest that nesting loggerheads in Georgia may set up residency adjacent to nesting areas up 56 days to prior to the start of the nesting season. Other sources of information regarding epibionts collected from loggerheads on Wassaw Island include Frick et al. (2000) and Frick, Williams and Veljacic (2000).

Table 8. Epibionts associated with nesting loggerhead sea turtles (*Caretta caretta*) on Wassaw Island.

Epibiont Species	Common Name
Porifera	**Sponges**
Cliona celata	Boring sponge
Haliclona loosanoffi	Eroded sponge
Mycale americana	Flabby sponge
Cnidaria	**Hydroids, Corals and Anemones**
Aiptasia pallida	Brown anemone
Anemonia sargassiensis	Sargassum anemone
Astrangia danae	Star coral
Calliactis tricolor	Hermit crab anemone
Diadumene leucolena	Pale anemone
Halocordyle disticha	Feather hydroid
Hydractinia echinata	Snail fur
Leptogorgia virgulata	Sea whip coral
Stylactis hooperi	Hooper's hydroid
Tubularia crocea	Wildflower hydroid
Mollusca	**Snails, Sea slugs and Bivalves**
Anadara ovalis	Blood ark
Brachidontes exustus	Scorched mussel
Chaetopleura apiculata	Eastern beaded chiton
Chione grus	Grey pygmy venus clam
Costoanachis avara	Greedy dove snail
Cratena pilata	Ivory sea slug
Crepidula fornicata	Atlantic slipper snail
Crepidula plana	White slipper snail
Doriopsilla pharpa	Lemon drop sea slug
Doris verrucosa	Sponge sea slug

Mitrella lunata	Lunar dove snail
Musculus lateralis	Zig-zag mussel
Rupellaria typica	Atlantic rock borer
Sphenia antilliensis	Soft-shelled clam
Platyhelminthes	**Flatworms**
Bdelloura candida	White flatworm
Oligaclado floridanus	Variable flatworm
Annelida	**Segmented worms**
Dorvillea sociabilis	Millipede polychaete worm
Filograna vulgaris	Lacy feather polychaete worm
Ozobranchus margoi	Marine leech
Podarke obscura	Swift footed polychaete worm
Procerea fasciata	Red, white and blue polychaete worm
Sabellaria floridensis	Florida mason polychaete worm
Syllis spongicola	Sponge polychaete worm
Arthropoda	**Crabs, Barnacles and Allies**
Ampithae ramondi	Amphipod
Balanus amphitrite	Acorn barnacle
Balanus eburneus	Ivory barnacle
Balanus trigonus	Pink-striped acorn barnacle
Callipallene brevirostris	Sea spider
Cancrion carolinus	Entonioscid isopod
Caprella andreae	Skeleton shrimp (amphipod)
Caprella equilibria	Skeleton shrimp (amphipod)
Caprella penantis	Skeleton shrimp (amphipod)
Chelonibia testudinaria	Temperate turtle barnacle
Chthamalus fragilis	Fragile barnacle
Chthamalus stellatus	Star barnacle
Colomastix halichondriae	Amphipod
Dulichiella appendiculata	Big-clawed amphipod
Lepas anatifera	Goose barnacle
Lepas pectinata	Goose barnacle
Lysmata wurdemanni	Peppermint shrimp
Menippe mercenaria	Stone crab
Panopeus herbstii	Atlantic mud crab
Paracaprella tenuis	Skeleton shrimp (amphipod)
Pinnotheres ostreum	Pea crab
Planes minutus	Columbus crab
Podocerus chelonophilus	Testudinous amphipod
Porcellana sayana	Spotted porcelain crab
Sphaeroma quadridentatum	Marine roly-poly
Stomatolepas praegustator	Barnacle
Bryozoa	**Moss animals**
Anguinella palmata	Bushy bryozoan
Bugula neritina	Bushy bryozoan
Membranipora tenuis	White crust bryozoan
Urochordata	Tunicates and sea squirts

Aplidium constellatum	Constellation tunicate or sea pork
Didemnum duplicatum	Paintsplash tunicate
Molgula manhattensis	Sea grape sea squirt
Perophora viridis	Honeysuckle tunicate
Plants	**Algae**
Bryopsis plumosa	Green plume algae
Calothrix sp.	Blue-green algae
Chaetomorpha sp.	Green algae
Cladophora sp.	Green algae
Ectocarpus sp.	Brown algae
Enteromorpha sp.	Green algae
Noctiluca sp.	Dinoflagellate
Polysiphonia sp.	Red algae
Unidentified green algae	Single-celled algae
Unidentified diatoms	Diatoms

DISCUSSION

Loggerheads deposit their nests within all six nesting habitat types found on Wassaw Island (Fig. 4; Table 1). However, habitat types with the greatest visual slopes are more often utilized (Fig. 4; Table 1), indicating that the slope of the beach may be an important nesting cue for loggerheads. A study and review by Wood and Bjorndal (1999) also implicates beach slope as an important cue for loggerheads during nesting emergences in Florida.

Comparing our tagging data to information collected from Little Cumberland Island (LCI), Georgia, several differences appear that are worthy of discussion. The population structure of LCI turtles reported by Richardson and Richardson (1981) is significantly different than the population structure presented here for Wassaw Island nesters. For instance, Richardson and Richardson (1981) reported that the average number of neophytes per season on LCI was 30-40 %, while immigrants, remigrants, and tag scarred turtles represented 60-70 % of the turtles observed per season, collectively. The observed average neophytes per season on Wassaw Island (70 %) and the collective averages of immigrants, remigrants, and tag scarred turtles (30 %) contrasts the data reported by Richardson and Richardson (1981). It should be noted that LCI's tagging project and the Caretta Research Project have used the same tagging methodologies throughout the entirety of both programs, so differing methodologies should not account for any major differences observed in population structure comparisons between the two programs. Instead, a few points might explain the differences between the two historical data sets. The beach on LCI (~ 4 km long) is considerably smaller than Wassaw Island's beach. A smaller beach would undoubtedly reduce the probability of missing turtles during nightly patrols and thus increase the number of remigrants observed in the future. Secondly, Jekyll Island (~ 3 km north of LCI) also supports a long-term saturation tagging program. As turtles shift their nesting efforts between the two islands, the number of immigrant turtles observed on LCI per season would increase and consequently, the number of neophytes observed per season would decrease. Moreover, there are no long-term saturation tagging programs neighboring Wassaw Island. The closest saturation tagging programs to Wassaw Island are Onslow Beach and Bald Head Island, North

Carolina (~ 230 km to the north) and Jekyll Island, Georgia (~ 85 km to the south). The lack of tagging programs neighboring Wassaw Island undoubtedly lowers the numbers of immigrants and tag scarred turtles we observe per season, and in turn, increases the number of neophytes we observe each season. Finally, the possibility exists that the large percentage of neophytes observed on Wassaw Island each season may also be attributed to the recruitment of 'new' turtles into the nesting population.

The remigration rate reported for Wassaw Island loggerheads (10.3%; 114/1110 turtles) is considerably lower than that reported by Richardson et al. (1978) for "Cumberland beaches" (68 %; 453/671 turtles). Richardson et al. (1978) combined remigration data collected from LCI with data collected from Cumberland Island (located immediately south of LCI; Fig. 1), hence the study area "Cumberland beaches". This point might help to explain such a large difference between our presented remigration rate and the rate reported by Richardson et al. (1978). Warranting the beaches surrounding Wassaw Island were extensively covered for nesting loggerheads, incorporation of such data into the Wassaw Island database would undoubtedly increase our remigration rate as some of our turtles are occasionally seen nesting on these islands. However, within this report we consider a remigrant to be one that was originally tagged on Wassaw Island and observed in following nesting seasons on Wassaw Island. Thus, tagged turtles observed on beaches adjacent to Wassaw Island were not considered to be remigrants.

The tag returns and recoveries documented by our program encompassed a similar range as reported for turtles tagged on LCI (Bell and Richardson, 1978; Fig. 5; Table 5). Figure 5 shows the distribution of tag returns and recoveries associated with Wassaw Island's saturation tagging program. The range of rookery beaches utilized by loggerheads, that also nest on Wassaw Island, encompasses ~ 800 km of coastline in the southeastern United States (Tables 5 and 6).

Long range tag return data obtained from adult female loggerheads is helpful when determining the nesting range utilized by an individual turtle. Such data can also be used to chart within season migrations undertaken by an individual turtle. However, a problem exists when gleaning information from tag returns since adult female loggerheads will also utilize the coastal region adjacent to rookery beaches as foraging grounds during years when they are not nesting (Musick and Limpus, 1997). Thus, it becomes difficult to determine if a tag return represents a reproductive or foraging migration if the turtle in question was not observed nesting, within the same season, prior to or subsequent to the tag return observation. For instance, tag return # 35 (Table 5) represents a turtle that nested in 1979, again in 1980 and was captured later that summer in a shrimp trawl operating off Tybee Island, not far away from where she was previously observed nesting on Wassaw Island. Taking an observation like this into account, one can not assume that a turtle observed nesting in one season and then captured the next season (not nesting) is an 'off-nesting season' capture, since loggerheads can nest in subsequent seasons.

Out of the 100 tag returns presented in Table 5, 12 turtles (return #'s 12, 14, 31, 34, 35, 46, 51, 61, 64, 68, 69 and 76; Table 5) were observed nesting on Wassaw Island prior to the aforementioned tag return observations. A general analysis of these returns shows nesting loggerheads moving north and south of Wassaw Island to other nesting beaches and coastal areas adjacent to rookery beaches throughout the summer (Table 5).

Turtles moving north of the study area appear to do so in late summer (mid-July to August), whereas; turtles migrating south of the study area do not show any such consistency and have moved southward throughout the nesting season (June-August). A more detailed analysis of the conditions surrounding each migration (i.e. weather conditions, phylogenic origin of the observed turtle, age of the turtle, etc.) are needed before any detailed conclusions derived from any long-range tag return data can be made.

Utilizing flipper tagging to track individual nesters is, by far, not the best methodology available (Witzell, 1998). However, it is an important methodology to adopt when conducting long-term studies that depend upon a large sample size to create averages that are representative of the overall nesting population (Balazs, 1999). Without a means to identify individual turtles, such studies would contain sampling errors as a result of duplicating sampling attempts or data collections on individual turtles that have already been sampled. Thus, it becomes important to evaluate the performance and reliability of the available tag types that are applied to nesting loggerheads.

Comparing the four tag types used on Wassaw Island from 1973-2000, plastic flipper tags applied to hind flippers and P.I.T. tags had the highest retention rates (Fig. 7). Inconel tags appear to be satisfactory for identifying turtles over an extended period of time, warranting they are replaced when the tags or tagging site begins to degrade (Fig. 6). However, since inconel tags were only tested on the foreflippers, it is possible that the retention rate of inconel tags on the hind flippers may be greater than that observed for inconel tags on the front flippers. Further study is needed to clarify retention rates between all tag types in respect to the available tagging locations on turtles.

Loggerhead nest monitoring from 1973-75 revealed that, without any type of nest protection on Wassaw Island, 100 % of the nests deposited would either be inundated by high tides or predated (Section 9). A 0% hatch rate for the 1973-75 years combined initiated a decision to protect nests beginning in the 1976 season. Although well intentioned, moving all nests to styrofoam coolers and 5-gallon buckets did not produce the highest hatch rates we have observed from Wassaw Island nests. However, the average hatch rate has increased substantially (to 71.4 %) by incubating nests on the beach (relocated and *in situ*) since 1979.

From our observations and studies on Wassaw Island, it is evident that more work is needed before we can fully understand the nesting ecology of loggerhead sea turtles. By supplementing long-term programs with newer methodologies and collaborative efforts from other scientific disciplines, we hope that such opportunities will provide us with newer angles by which to view our historical data. However, there is still the need for other programs to report their long-term data sets so that accurate comparisons and management decisions can be generated.

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Literature Cited

Balazs, G. H. 1999. Factors to consider in the tagging of sea turtles. Pages 101-109. In: Eckert, K. L., K. A. Bjorndahl, F. A. Abreu-Grobois and M. Donnelly (Eds). Research and Managements Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

Bell, R. and J. I. Richardson. 1978. An analysis of tag recoveries from loggerhead sea turtles (*Caretta caretta*) nesting on Little Cumberland Island, Georgia. Florida Mar. Res. Publ. 33:39-44.

Bowen, B. W. and S. A. Karl. 1997. Population genetics, phylogeography, and molecular evolution In: Lutz, P. L. and J. A. Musick (Eds.). Biology of Sea Turtles, pp. 29 -50. CRC Press, Boca Raton, 432 p.

Caldwell, D. K. 1959. The loggerhead turtles of Cape Romain, South Carolina. (abridged and annotated manuscripts of W. P. Baldwin, Jr. and J. P. Loftin, Jr.). Bull. Fla. State Mus. Biol. Sci. 4:319-348.

Dodd, C. K., Jr. 1988. Synopsis of the biological data on the loggerhead sea turtle (*Caretta caretta*) (Linnaeus 1758). U. S. Fish and Wildl. Serv., Biol. Rep. 88(14). 110 p.

Frick, M. G., K. L. Williams and M. Robinson. 1998. Epibionts associated with nesting loggerhead sea turtles (*Caretta caretta*) in Georgia, USA. Herpetological Review. 29(4): 211-214.

Frick, M. G., K. L. Williams, D. Veljacic, J. A. Jackson and S. E. Knight. 2000. Newly documented epibionts associated with nesting loggerhead sea turtles (*Caretta caretta*) in Georgia, USA. Marine Turtle Newsletter No. 88.

Frick, M. G., K. L. Williams and D. Veljacic. 2000. Additional evidence supporting a cleaning association between epibiotic crabs and sea turtles: How will the harvest of sargassum seaweed impact this relationship? Marine Turtle Newsletter No. 90.

Frick, M. G., K. L. Williams, D. Veljacic, J. A. Jackson, and S. E. Knight. In press. Epibiont community succession on nesting loggerhead sea turtles (*Caretta caretta*) from Georgia, USA. Proceedings of the 20th Symposium of Sea Turtle Biology and Conservation, Orlando, FL. March 1-4, 2000.

Johnson, A. S., H. O. Hilestad, S. F. Shanholtzer and G. F. Shanholtzer. 1974. An ecological survey of the coastal region of Georgia. Natl. Park Serv. Sci. Monogr. Ser. No. 3.

Limpus, C. J. 1992. Estimation of tag loss in marine turtle research. Wildl. Res., 19:457 -69.

Margaritoulis, D. 1985. Preliminary observations on the breeding behaviour and ecology of *Caretta caretta* in Zakynthos, Greece. Biologia Gallo-Hellenica 10: 323-332.

Musick, J. A. and C. J. Limpus, 1996. Habitat utilization and migration in juvenile sea turtles. P. 137-164. In: P. L. Lutz and J. A. Musick (eds.). The Biology of Sea Turtles. CRC Press, Boca Raton, FL.

Richardson, T. H., J. I. Richardson, C. Ruckdeschel, and M. W. Dix. 1978. Remigration patterns of loggerhead sea turtles (*Caretta caretta*) nesting on Little Cumberland and Cumberland Islands, Georgia. Florida Mar. Res. Publ. 33:39-44.

Richardson, J. I. and T. H. Richardson. 1982. An experimental population model for the loggerhead sea turtle (*Caretta caretta*). Pages 165-176 in K. Bjorndal (ed.), Biology and Conservation of Sea Turtles. Smithsonian Institution Press, Washington, D.C.

Richardson, J. I. 1999. Priorities for studies of reproduction and nest biology. Pages 9 -11. In: Eckert, K. L., K. A. Bjorndal, F. A. Abreu-Grobois and M. Donnelly (Eds). Research and Managements Techniques for the Conservation of Sea Turtles. IUCN/SSC Marine Turtle Specialist Group Publication No. 4.

Turtle Expert Working Group. 1996. Status of the loggerhead turtle population (*Caretta caretta*) in the western North Atlantic, 50 p.

van Dam, R. P. and C. E. Diez. 1999. Differential tag retention in Caribbean hawksbill turtles. Chelonian Conservation and Biology 3(2):225-229.

Witzell, W. 1998. Messages in bottles. Marine Turtle Newsletter. Vol. 40:3-5.

Wood, D. W. and Bjorndal, K.A. 2000. Relation of temperature, moisture, salinity, and slope to nest site selection in loggerhead sea turtles. Copeia 2000(1): 119-28.